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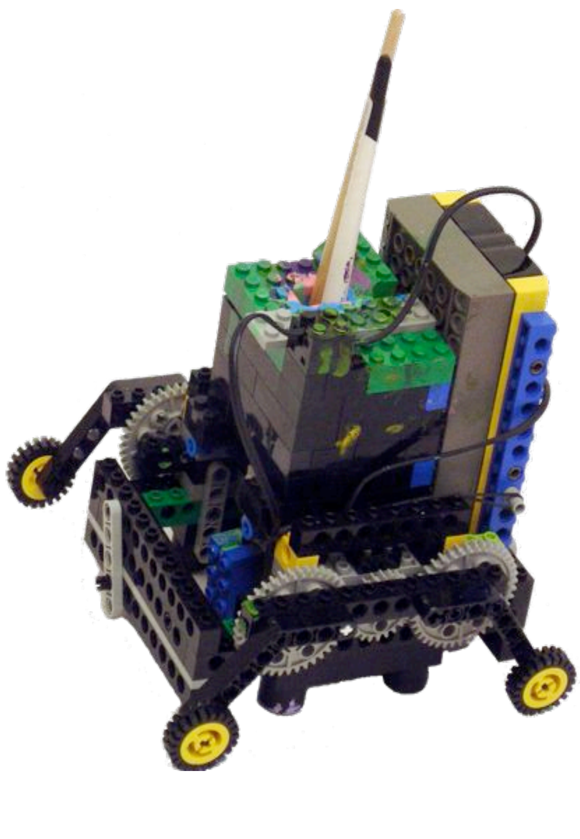
Autonomous Robots That Paint



Max Chandler's Gimpy 2, and Leonel Moura's robotic action painter

AUTONOMOUS ROBOTS THAT PAINT
Loren Means

I think of robots as works of art, and roboticists as artists, as well as philosophers. So I'm doubly delighted when I run across roboticists who create robots that themselves create art.

The history of robotics has two phases: first, the top-down approach, and second, the bottom-up approach. The top-down approach posited a robot that was intelligent enough to understand most aspects of its environment before venturing into it. The problem was, these robots were never intelligent enough, and so took an inordinate time to plot each motion in the world. The bottom-up approach, pioneered by Rodney Brooks, put many robots with low intelligence into the world with little knowledge of their environment, and allowed them to learn how to function on their own. In the process, two concepts helped the robots manifest themselves. One such concept was swarm intelligence, the mimicking of natural entities such as birds, bees, and flies in the way they cooperate to achieve goals, and stigmergy, the ability of these entities, such as ants, to communicate with each other without encountering each other directly, for instance by the planting of pheromones by one ant to suggest corresponding behavior in other ants.

Science fiction writers such as Olaf Stapeldon, Isaac Asimov, and Vernor Vinge have postulated group minds that, in cooperating with each other in adequate numbers, are able to create an intelligence that rivals that of an individual human. Swarm intelligence, on the other hand, creates an intelligence that mimics non-human intelligence, and the art created by these swarm intelligences is itself a manifestation of forms that are like those found in nature, rather than the kinds of mimetic art that human artists are taught to execute. In other words, the art is non-objective, or "abstract," and often of a very high order. This intelligence is closer to "machine intelligence" than human intelligence.

Although the creation of art by computers, using generative techniques, has produced a formidable body of work, the creation of art by autonomous robots is relatively new, probably because the bottom-up approach deprives robots of the processing power that today's computers make available for artistic creation. Computer-art algorithms usually consist of two essential elements: a generative element that allows the computer to create, and an aesthetic neural network that evaluates the quality of the work created and tells the computer what to discard, and when a work of art is finished.

Leonel Moura's swarm robots don't have the individual processing power to manifest neural networks, and so he found it necessary to intervene and stop the swarm process when he felt the work was completed. His new RAP robot, on the other hand, has more aesthetic ability, and can finish and even sign its own works. Max Chandler's robots are closer to the RAP model, but Chandler is intimately involved in the painting process with his robots, loading their paint containers and stopping the painting process to wait for paint to dry.

Since I do generative art in both the visual and the sound media, and try to get similar results in both, I've been pondering the differences between the two. I think the fundamental difference is that music is a strictly temporal art, like dance and theater, in that no object is created. Visual art, on the other hand, produces an object, and that object constancy is what makes it easier to generate complex forms. When you make music, you have to keep remaking it from second to second, as it evaporates, as Eric Dolphy put it, "into the air." Whereas when you make a mark on a surface, the mark remains, and accumulates as more marks are added, until complexity is achieved. These marks that remain can serve as the equivalent of pheromones, which would suggest why robots paint, but, as far as I know, don't as yet make music. (Although Tim Blackwell has used swarm intelligence with improvising jazz musicians for several years, creating computer graphic displays that the musicians react to: http://www.timblackwell.com.)

Max Chandler is a long-time YLEM supporter who splits his time between San Francisco and Scottsdale, Arizona. He has been interviewed in *NewScientist*, and has shown his robots at Siggraph and RoboNexus. Chandler studied math at MIT, Chinese at the Defense Language Institute, and did graduate study work with the Taiwanese painter Chen Ting-shih. Chandler has worked in both hardware and software with ten patents in milk cartons, gymnastic equipment, scanners, film recorders, compiler techniques, CAD, and UI. He also programmed such products as Laplink, SimCity 3000, and The Sims. As he put it in a recent interview: "I think reality has three components: the material world, the natural laws that describe how that world behaves, and the mathematics at the foundation of those laws. To me, art that considers each of these components is much more realistic than paintings that look like photos."

I found Leonel Moura on the Web at www.lxxl.pt while doing research on swarm robotics. Moura is a Portugese conceptual artist who has worked with AI and robotics since 2001. In 2003, he created his first swarm of 'Painting Robots' able to produce original artworks based on emergent behavior. Since then he has produced several Artbots, each time more autonomous and sophisticated. RAP (Robotic Action Painter), 2006, created for a permanent exhibition at the American Museum of Natural History in New York, is able to generate highly creative and original art works, to decide when the work is ready and to sign it, which it does with a distinctive signature. In 2007 he opened the Robotarium, the first zoo dedicated to robots and artificial life, in Portugal. Moura has written several books on the subject, among which are *Architopia*, 2001, *Man and Robots*, 2004, and *Robotarium*, 2007.

YLEM Forum: Accessing Biology Through Art
Thurs., November 8th at 8 pm
Canessa Gallery
708 Montgomery (upstairs)
San Francisco, CA

As this program shows, biology in so many ways is a very visual subject. At the molecular level, this is more of a problem, but one of the speakers, a graduate in microbiology, manages to convey its ideas using vivid paintings that use, on occasion, metaphors from mythology. Learn more about biology in an enjoyable way!

PROGRAM

Donna Billick: Paintng murals with science students
"Neither science nor the arts can be complete without combining their separate strengths"
–E. O. Wilson.

Our Art/Science Fusion program is a new paradigm for teaching and learning at the University of California Davis Campus. Through interactive, experiential-based lectures and studio time, students learn scientific concepts and turn them into works of art. The unity of knowledge is introduced, a sharing across borders and disciplines, where students see and feel art and science in the context of creating art, using the mediums of ceramic, paint and textiles. With this experience, students learn to transform ideas into new concepts and insights with a greater appreciation for the natural world. Our presentation will showcase the design, fabrication and installation of the large-scale public art created in the Art/Science Fusion program. Nature's Gallery is a new work displayed in the US Botanic Garden in Washington DC. "Tree of Life" is a 10' high x 17' wide ceramic mosaic mural at the UC Davis Arboretum. In addition, there will be images of painted murals and textiles.

Donna Billick offers 32 years creating large-scale public art in America, and around the world. I believe that the issue of collective meaning and purpose is essential and urgent, due to environmental pressures. Our social choices and outcomes are shaped by two systems, our nature or physical world and our cultural heritage or artifacts. I believe a parallel vision for a future that supports our mind, body and soul is created in fusion concepts.

Julie Newdoll: Paintings based on microbiology
Emotions, states of being, and nature have been personified throughout time by many cultures in the form of various gods, goddesses and mythical characters. Julie Newdoll asks the questions, "Just as Bacchus can represent wine and the state of intoxication, Venus love, and Mars war, what would the personality of a goddess for estrogen be like? What would be her life story? Our imaginations seek to see things in nature in order to make sense of them. We see constellations in the stars and faces in the clouds.

What would we see in an electron microscope image if we looked long enough?" Newdoll's artwork has been featured on over 20 scientific journal covers in the last few years, and her paintings have been shown in both science and art venues internationally. Newdoll earned a B.A. in microbiology from the University of California at Santa Barbara, and an M.S. in medical illustration from the University of California at San Francisco. You can find her work on the web at http://www.brushwithscience.com and the Brush with Science Gallery, 3515B Edison Way, Menlo Park, California (650) 440-0084.

Shoshanah Dubiner's biological images
We will project 11 paintings by Shoshanah Dubiner of Ashland, Oregon, who has been fascinated by biological forms for many decades. After a recent Cell Biology class at Southern Oregon University, Shoshanah is turning her attention to the structures of the living cell, especially the cell membrane. She brings humans into all the landscapes, so viewers can imagine themselves more fully in the world of nature. Thus in "Membranes #1," the cell at the top left is also the head of a woman; the cell membrane becomes the skin that encloses her body; the words issuing from her mouth take on a life of their own, as do all the artifacts of human culture, including artists' paintings.

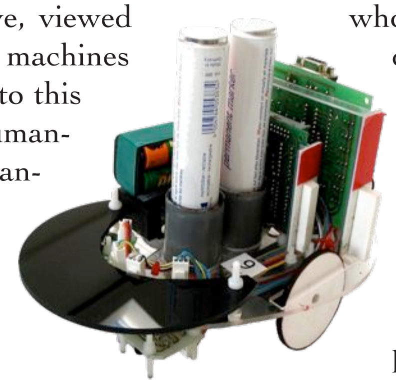
Membranes #1 by Shoshanah Dubiner, 2007, gouache on paper

ROBOT ART: A NEW KIND OF ART

Leonel Moura
http://www.leonelmoura.com

Mankind has been intrigued by the possibility of building artificial creatures. For the ancient Greeks this possibility was provided by techné, the procedure that Aristotle conceived to create what nature finds impossible to achieve. Hence, under this view, techné sets itself up between nature and humanity as a creative mediation.

This was the path taken by Norbert Wiener as he opened up the cybernetic perspective, viewed as the unified study of organisms and machines [1]. One line of development linked to this approach gave rise to the familiar humanoid robot, inspired by the von Neumannian self-replicating automata and based on the top-down attitude of the earliest Artificial Intelligence [2]. A much more interesting trend, also stemming from the seminal work of Wiener but intended to "take the human factor out of the loop," emerged in the mid-1940's with William Grey Walter, who proposed turtle-like robots that exhibit complex social behavior. This was the starting point for a new behavior-based robotics, abolishing the need for cognition as mediation between perception and plans for action.



Ant-like robot from the ArtSBot project

This line of research was pursued in the 1980's by Rodney Brooks [3], who began building six legged insect-like robots at MIT. This new generation of robots was based on Brooks' "Subsumption Architecture," which describes the agent as composed of functionality distinct control levels under a layered approach. The addition of new layers doesn't imply changes in the already existing layers. The aforementioned control levels then act in the environment without supervision by a centralized control or action planning centre. Also, no shared representation or any low bandwidth communication system is needed.

The most important concept in Brooks´ reactive robots is "situatedness," which means that the robot's behavior refers directly to the parameters sensed in the world, rather than using inner representations. Linked to this concept is the "embodiment" feature, which corresponds to the fact that each "robot is a physical body and experiences the world directly through the influence of the world in that body".

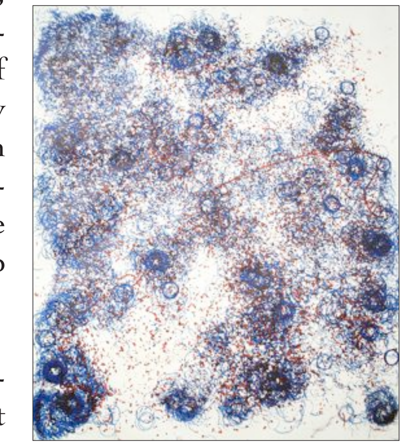
The idea of collective robotics appeared in the 1990's from the convergence of the above described Brooks' architecture with a variety of bio-inspired algorithms, focused on new programming tools for solving distributed problems. These bio-inspired algorithms stemmed from the work of Christopher Langton, who launched a new avenue of research in AI denoted Artificial Life that "allows us to break our accidental limitations to carbon-based life to explore non-biological forms of life" [4].

The well-known collective behavior of ants, bees and other eusocial insects provided the paradigm for the swarm intelligence approach of aLife. This bottom-up course is based on the assumption that systems composed of a group of simple agents can give rise to complex behavior, which depends only on the interaction between those agents and the environment. Such an interaction may occur when the environment itself is the communication medium and some form of decentralized self-organized pattern emerges without being planned by any exterior agency.

Stigmergy

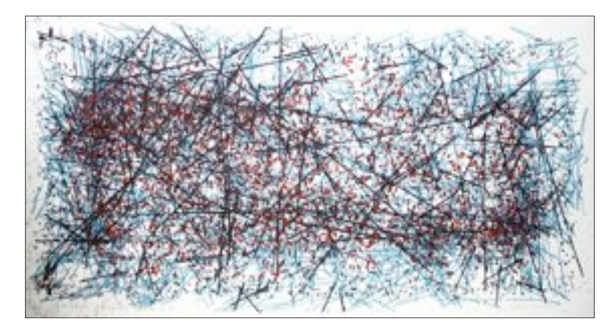
A swarm of ant-like robots at work

Based on ants and other social insect's studies [5], I have tried to reproduce artificially a similar emergent behavior in a robot swarm. These insects communicate among themselves through chemical messages, the pheromones, with which they produce certain patterns of collective behavior, like follow a trail, clean up, repair and build nests, defense and attack or territory conquest. Despite pheromones not being the exclusive way of communication among these insects — the touch of antennas in ants or the dance in bees are equally important — pheromonal language produces complex cognition via bottom-up procedures. Pheromone expression is dynamic, making use of increments and decrements, positive and negative feedbacks. Messages are amplified when a pheromone is reinforced, and lose "meaning" when a breeze disperses it. It is also an indirect form of communication, coined *stigmergy* by Grassé [6], from the Greek stigma/sign and ergon/action. Between the individual who places the message and the one who is stimulated by it, there is no proximity or direct relation.



ArtSBot 020404

Following these principles, I have replaced pheromone by color in my first ant-robots (2001). The marks left by one robot triggers a pictorial action in other robots. Through this apparent random mechanism abstract paintings are generated, which reveal well-defined shapes and patterns. These robots create abstract paintings that seem at first sight just random doodles, but after some reflexive observation, color clusters and patterns become patent. Through the recognition of the color marks left by a robot, the others react to it, reinforcing certain color spots. The process is thus everything but arbitrary. As far as I know, ArtSBot (Art Swarm Robots) [7] was the first art project to use emergent organization for developing robot creativity. Every previous experiment focused exclusively on randomness or sometimes on target strategies leading the machines to fulfill a pre-determined program created by the human artist. On the contrary, ArtSBot was meant to put into practice the utmost possible machine autonomy, aimed at producing original paintings. In operational terms, ArtSBot consists of a series of small "turtle" type robots, equipped with two felt pens and a pair of RGB sensors pointing to the painting plan. With these "eyes" the robots seek color (chromotaxis), determine if it is hot or cold, choose the corresponding pen and strengthen it by a constant or variable trace. To begin the process, when the canvas is still blank, the robots leave here and there a small spot of color randomly. Based on these simple rules, unique paintings are produced: from a random background stands out a well defined composition with intense shapes of color. In other words, initial randomness generates "order." The process is emergent and based on the properties of stigmergy.

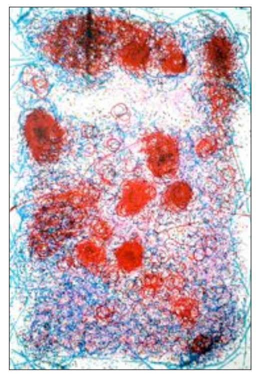


ArtSBot 280404

Machine creativity

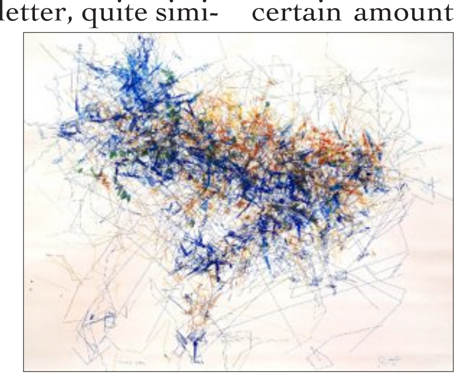
The artistic product of these robots is entirely original. In the same way that somebody who writes a book cannot be considered as a mere instrument of his primary school teacher, robots cannot be seen as simple instruments of the artist that conceived and programmed them. There is an effective incorporation of new and non predetermined information in the process. And that cannot be called anything but creativity. It is true that consciousness is lacking in this creativity. But if we look at the history of modern art, it is obvious that, for example, Surrealism tried to produce art works exactly in these same terms. The "pure psychic automatism," the quintessential definition of the movement itself, appeared as a technique that was spontaneous, non-conscious and without any aesthetic or moral intention. In the first *Surrealist Manifesto*, André Breton (1924) defined the concept in this way: "Pure psychic automatism by which it is intended to express, either verbally or in writing, the true function of thought. Thought dictated in the absence of all control exerted by reason, and outside all aesthetic or moral preoccupations." [8]. In the field of the visual arts, Pollock better fulfills this intention by splashing paint onto the canvas with the purpose of representing nothing but the action itself. This was coined *Action Painting*. Perhaps, because of that, the first paintings from my robots are, aesthetically, similar to those of Pollock or André Masson, another important automatism-based painter. In his surrealist period, Masson tried frequently to prompt a low conscious state by going hungry, not sleeping, or taking drugs, so that he could release himself from any rational control and therefore let emerge what at the time, in the path of Freud, was called the subconscious. The absence of conscious, external control or pre-determination allow these painting robots to engender creativity in its pure state, without any representational, aesthetic or moral intention.

RAP (Robotic Action Painter), created in 2006 for the Museum of Natural History in New York, is an individualist artist and not a swarm, but makes use of the same composition methods based on stigmergy and emergence. This robot is additionally able to determine, by its own means, the moment in which the painting is finished. Previous versions didn't have this capacity, being conditioned by battery discharge or my will to stop the process. RAP's decision is taken based on the information that it gathers directly from the painting, which produces a considerable variation of time and form, since RAP can decide that the work is complete after a relatively short while (entailing accordingly a low pictorial expression) or can extend the picture construction for a quite long period, making it much more dense and complex. The "secret" of this behavior is in the significant change of the sensors, which passed from two to nine "eyes," allowing now the reading of local patterns, in addition to color spots. RAP is also my first robot to sign its works.


ArtSBot 010504

ISU, the poet robot also created in 2006, has the ability to write letters and words producing poems and emergent compositions based on the letter, quite similarly to the Lettrism style, an artistic movement that followed Surrealism.

These references to 20th century art movements do not seek any kind of historical legitimacy, but are intended simply to show how certain morphogenesis processes produce similar results in human as well as non-human artists. Demonstrating, in the path of Rodney Brooks, how human nature can be seen to possess the essential characteristics of a machine.


RAP 250807

RAP's behavior

RAP is equipped with a grid of 3x3 color detection sensors, eight obstacle avoidance sensors, a compass, a microcontroller and a set of actuators for locomotion and pen manipulation. The microcontroller is an onboard chip, to which the program that contains the basic rules is uploaded through a PC serial interface.

The algorithm that underlies the program uploaded into RAP's microcontroller induces basically two kinds of behavior: the random behavior that initializes the process by activating a pen, based on a small probability, whenever the color sensors read white; and the positive feedback behavior that reinforces the color detected by the sensors, activating the matching color pen. These two distinct behaviors are described as modes: the Random Mode and the Color Mode. In the random mode RAP searches for color (chromotaxis). If a sufficient amount is not found (threshold) RAP activates here and there, randomly, a pen stroke choosing also randomly the color and the line configuration. The shape, orientation and extent of these initial lines are determined by the robot based on a random seed acquired from its relative position in the space. This is done with the data retrieved by the onboard compass. In this way RAP's random generator can be described as real random and not pseudorandom.

When a certain amount of color is detected the robot stops the random behavior and changes to color mode. In this phase RAP only reacts to the spots where a certain amount of color is found, reinforcing it with the same tone.

After a while a discrete pattern emerges, where from a general random background a well-defined composition can be recognized.

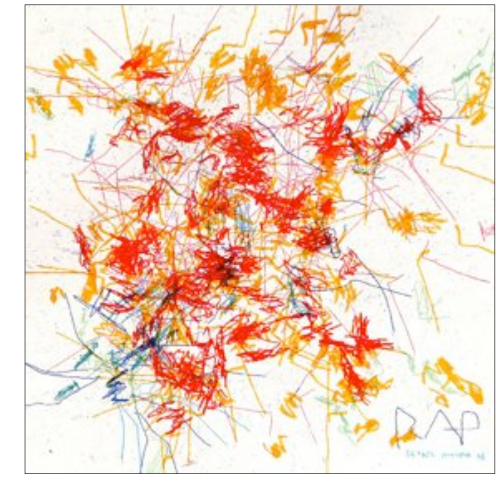
In order to determine when the painting is finished, RAP makes use of a grid of 3x3 RGB sensors. If a certain pattern is found, the robot "considers" the work to be done, moves to the down right corner and signs.

RAP creates artworks based on its own assessment of the world. At any given moment the robot "knows" its situation and acts accordingly. It scans constantly the canvas for data retrieving. It uses its relative position in the space as a real random generator. It builds gradually a composition based on emergent properties. It decides what to do and when to do it. It finishes the process using its particular sense of rightness.

Although the human contribution in building the machine and feeding it with some basic rules is still significant, the essential aspects of RAP's creativity stem from the information that the robot gathers by its own means from the environment. In this sense RAP's art must be seen as an original creation independent of the human artist that was at the origin of the process.

A new kind of art

My painting robots were created to paint. Not my paintings but their own paintings. The essence of their creations stem from the machines' own interpretation of the world and not from its human description. No previous plan, fitness, aesthetical taste or artistic model is induced. These robots are machines dedicated to their art.


RAP 180906

Such an endeavor addresses some of the most critical ideas on art, robotics and artificial intelligence. Today we understand intelligence as a basic feedback mechanism. If a system, any system, is able to respond to a certain stimulus in a way that it changes itself or its environment, we can say that some sort of intelligence is present. 'Sheer' intelligence is therefore something that doesn't need to refer to any kind of purpose, target or quantification. It may plainly be an interactive mechanism of any kind, with no other objective than to process information and to react in accordance to available output capabilities.

Hence and although my starting point was bioinspiration, in particular modeling social insects' emergent behavior, the idea was to construct machines able to generate a new kind of art with a minimum of fitness constraints, optimization parameters or real life simulation. It is the simple mechanism of feedback and stigmergy that is at work here.

These artistic robots are singular beings, with a particular form of intelligence and a kind of creativity of their own. They do art as other species build nests, change habitats or create social affiliations. But since we humans are for the time being the only pensive observers, the relation between machine art and human aesthetic principles is here the central issue. Many people like the robot paintings, probably because we seem to gladly embrace fractal and chaotic structures. But, more than shapes and colors, what some of us really appreciate in this idea and its associated process is the fact that it questions some of our strongest cultural convictions. Art was supposed to be an exclusive matter of mankind. In this sense, the robot paintings are a provocative conceptual art that problematizes the boundaries of art as we know it.

References

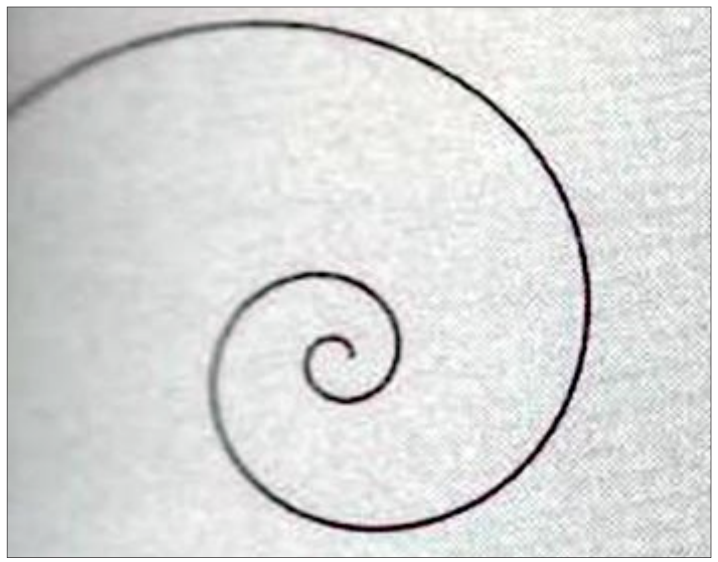
[1] Wiener, N. (1948) *Cybernetics; or the Control and Communication in the Animal and the Machine*, MIT Press.
[2] von Neumann (1966) *Theory of self-reproducing automata*, ed. By A.W. Burks, University of Illinois.
[3] Brooks, R., (1991) *Intelligence without Reason*, Proc. 12th IJCAI, Ed. Morgan Kauffmann, San Mateo and Brooks, R., (2002) *Flesh and Machines: How Robots Will Change Us*, Pantheon Books.
[4] Langton, C. (1987) *Proceedings of Artificial Life*, Adison-Wesley.
[5] Wilson, Edward O. (2006) *Nature Revealed, Selected Writings 1949-2006*, The Johns Hopkins University Press, Baltimore.
[6] Grassé, P. P. (1959) *La réconstruction du nid et les coordinations inter-individuelles chez bellicositermes natalienses et cubitermes sp. La théorie de la stigmergie: Essai d'interpretation des termites constructeurs*, Insectes Sociaux, 6, pp. 41-48.
[7] Moura, L. and Pereira, H.G. (2004) *Man and robots: Symbiotic Art*, Institut d'Art Contemporain, Villeurbanne.
[8] Breton, André (1969) *Manifestoes of Surrealism*, University of Michigan Press.

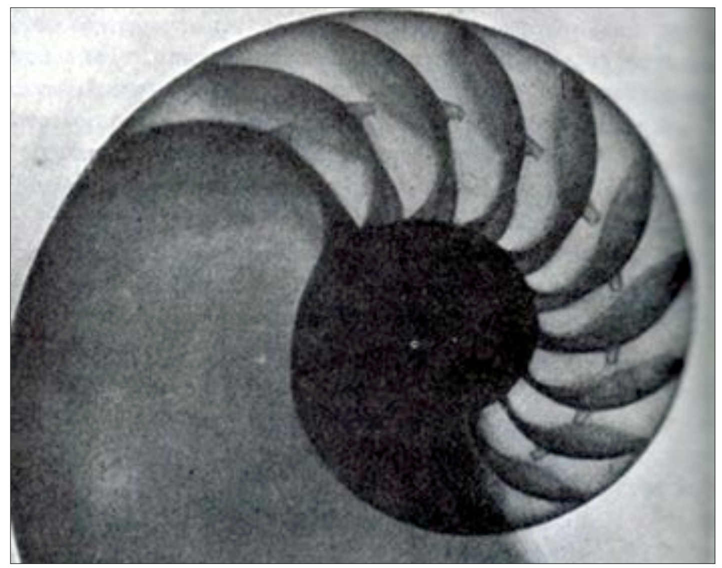
CHANCE IN ROBOTIC PAINTING

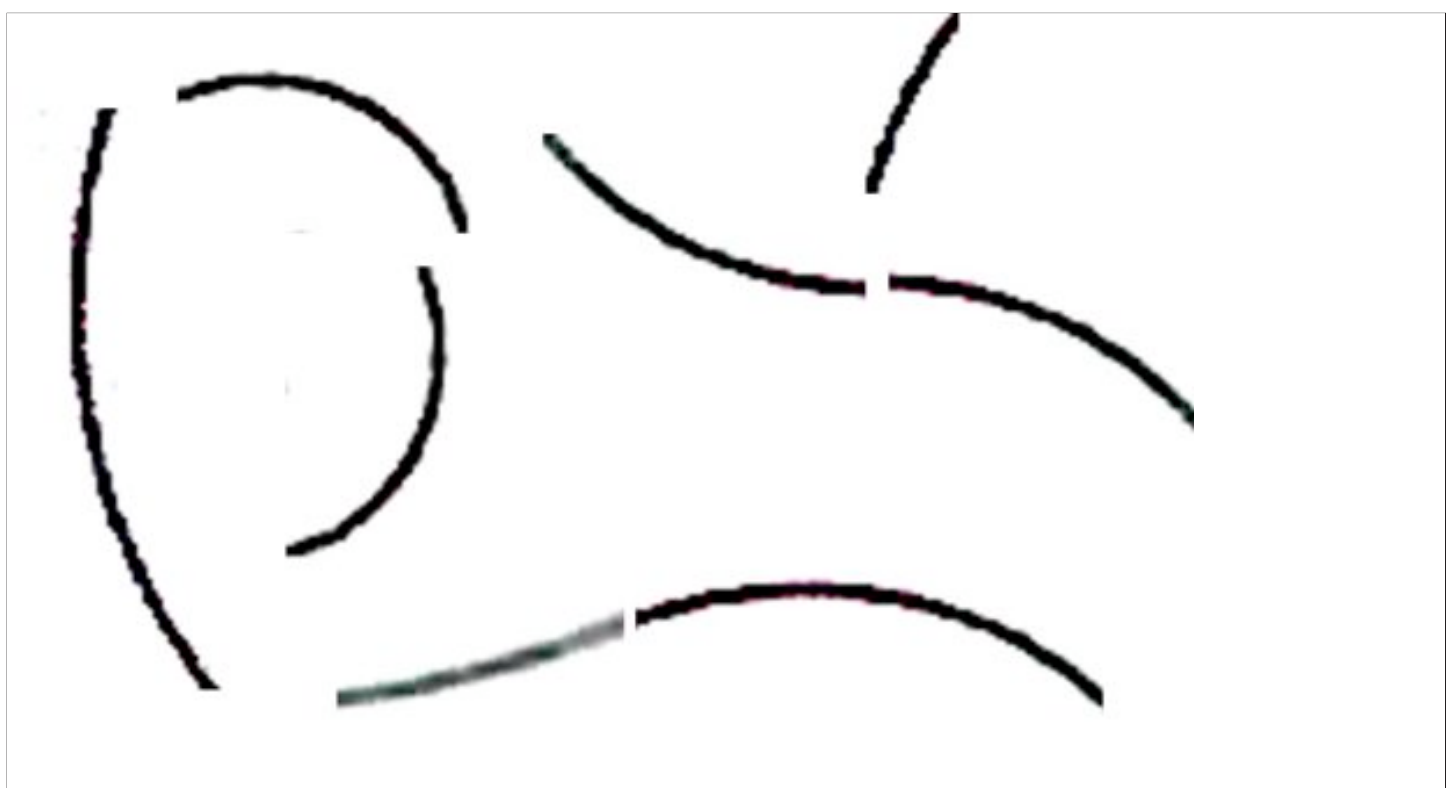
Max Chandler
http://www.maxchandler.com

"The original movement, the agent, is a point that sets itself in motion (genesis of form). A line comes into being. It goes for a walk."
–Paul Klee

Paul Klee wrote a short text he titled "Taking a Line for a Walk." To give this idea a 21st century twist, I make autonomous mobile robots that are small enough to walk around the canvas using paint brushes to make marks. The robots have a small computer on board and sensors that can see the surface of the canvas and the marks it has already made. I use these robots a as a tool for painting — as a super brush that can make marks that humans cannot make alone. For instance, the robots can stay much closer to the actual lines of living growing things than we can with hand eye coordination. They are also capable of truly random behavior that brings them closer to natural variation.

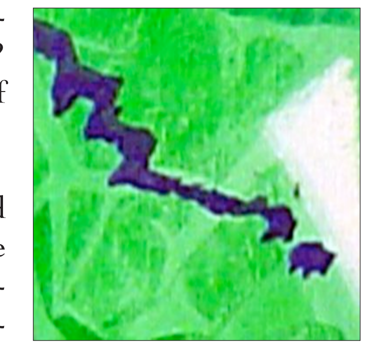






Fragments of a logarithmic spiral

I wish to make art that reflects our common lives. Two aspects of 21st century life are inescapable. First is the continuing discoveries and refinement of knowledge through science. I think the contemporary disrespect and distrust of science may be temporarily fashionable, but is certainly eternally foolish. Second, most of us have become personally engaged with technology. Technology is no longer limited to impacting our work lives, smart devices have a role in our personal lives as well. Who would claim their daily lives are not changed by one or more of the following devices: cell phone, TIVO, Blackberry, Notebook Computer, Intenet Search Engine, eMail Servier,...? Cell phones are a constant companion of many people today.



These are all smart devices that depend upon small to large computers that are part of their make up. These devices involve a combination of mechanics, electronics, controllers, and programming. Using a similar tool to make art reflects who we are and our lives today. I use simple, very focused, small robots as a tool to integrate both aspects into an art that is science informed and engaged with technology in obvious and not so obvious ways. I have seen many art projects that use similar devices.

ELF is an art team from Germany that makes small insect-like robots that they display in jars. The robots chirp, kick against the jars and struggle to climb out. It is an interesting display that takes on a special slant when you see their film. The film shows these robots "living" in natural settings — trees, grass, beaches, etc. — then people come along, collect them and place them into the jars. Because the jars are European, American viewers may not get it right away. If they were in the same mason jars they we used to capture fireflies or other insects as kids then our experience would be like the European viewer. Many of us have treated living creatures the way these robots have been treated.

Mark variation due to COGS

Ken Goldberg, a prominent artist in the Bay Area, often uses robots in collaborative social environments where people all over the globe can direct these robots in various tasks. One of his best known works was a garden tending by a robot that was controlled by users through the Internet.

Artists like these are using robots as part of a larger vision. The robot is a tool or a component of the work rather than a substitute for the artist. This is much closer to the actual use and capabilities of robots than earlier approaches.

Great advances have been made in recent years in thinking about small robots. Through the work of Rodney Brooks, Mark Tilden, and many others, we now realize that simple robots, managing simple behaviors, are often much more successful than robots that try to be substitute humans or pursue humanlike solutions.

Most people realize that painting with robots involves calculations — many calculations. To just move around an autonomous mobile robot uses calculations for motor control, position deduction and so on. Also, mathematics provides a rich palette of shape description functions. I choose from algorithms that the shapes, lines and patterns in growth of living organisms. There are many texts that explain the mathematics that explain natural shapes and growth patterns. Here are a few:

"The Self Made Tapestry" and "Critical Mass" by Philip Ball
"The Algorithmic Beauty of Sea Shells" by Meinhardt, et al
"The Algorithmic Beauty of Plants" by Prusinkiewicz and Lindenmayer
"On Growth and Form" by D'Arcy Thompson
"A New Kind of Science" by Stephen Wolfram

Article continued on the next page

My cacti series of paintings use fragments of logarithmic spirals for edges and lines and cellular automata rules for shape selection and placement.

The prickly pear cactus family (*Opuntia*) is a group of plants whose growth is amazingly like cellular automata. Its pads are like cells in that they are mostly alike and their number, position and type depend upon the number, position and type of their neighbors. Each pad uniquely defines the cactus. You can propagate the plant by cutting off a pad and placing partly in the ground. One method the plants use for propagation is to drop pads onto the ground when they become crowded or water becomes scarce. The pads get moved by animals and take root in a new location. There are three basic types of pads. Base pads connect to the root systems and later (20 to 70 years later) turn into woody trunks and branches. End pads flower and produce fruit for one or more years and then produce a number of new end pads. The bulk of the pads are links between base and end pads. The number and branching of links varies by species. Although as many as ten new end pads can be generated, all but one or two (in some species, three) of the pads will drop off in the next few years. Which pads remain to become the structure of the plant have a cellular automata like dependency upon its neighbors.

To me, a great danger of art with robots is that it can become predictable, routine, even rubber stamp-like.

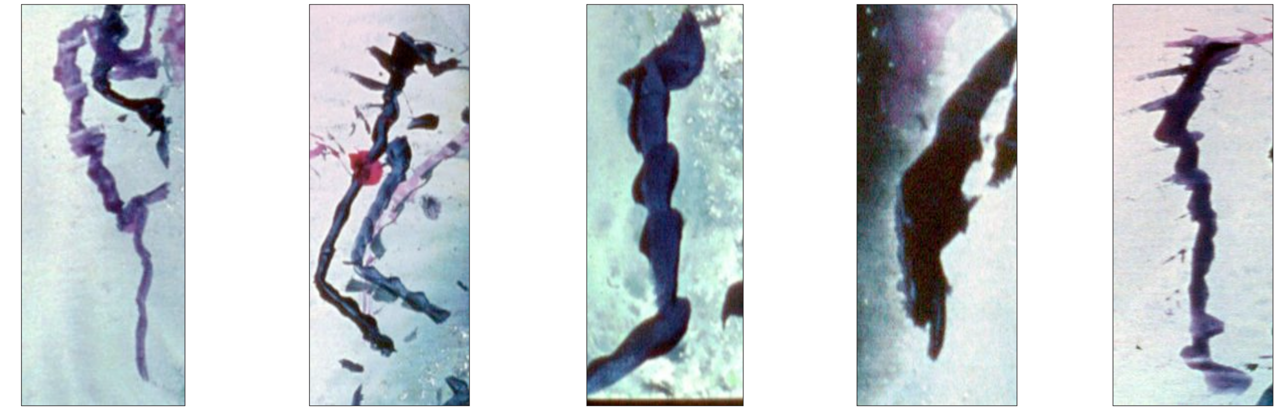
If you look at a group of blossoms on a plant you can see two characteristics. First, each flower is logically composed the same way, with the same center and pattern of petals. Second, no two of the actual flowers are physically alike. The orientation of the bloom to the sun and the plant varies. Some petals are slightly shorter, some twist, some turn down, and on and on.

Robotic devices can use several tactics to obtain this natural variation.

Most of my robots are walking robots, which have center of gravity shifting (COGS) as they walk. Of course, anything that walks has COGS, humans included. Design of walking robots often concentrates on limiting COGS effects by shifting weights, twisting ankles, etc. My robots take the opposite direction to capitalize on COGS effects and the resulting impact on brush dynamics. GIMPY1, for instance, is unusually wide for an autonomous mobile robot, as a way to emphasize COGS effects.

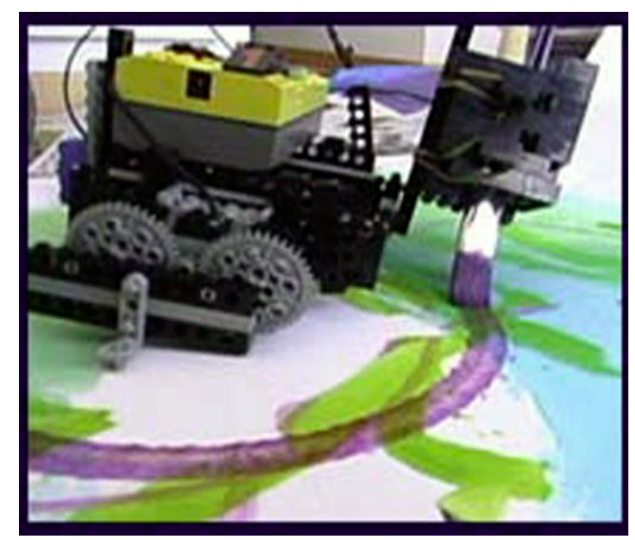
Randomization has been used in art in the past by Duchamp, Cage, Johns, and others. These artists have mostly used dice as a source of random numbers for selection or placing content in their images. Dice are a very weak source of random numbers compared to the capabilities of even simple microcontrollers. Even 8-bit microcontrollers that support Java have 32-bit random number generation, which is like rolling millions of dice. We use this capability to control the range, precision, and randomness of the numbers far, far beyond the reach of dice. Early randomization in art was just moving erratically through a small (often very small) pattern. Today, we can actually get much closer to natural variation.

My robots are almost all programmed in Java, so a lot of the code is reused between them. To do this I have a profile for each robot including forward speed, turning speed, balancing factors, sensors thresholds, hysteresis, etc. I can add or subtract a random amount to these profiles to produce smoothly varying behaviors for the robot during the course of making an image.



Mark variation due to randomization

Because nearly all of my robots depend upon two motors for forward motion there is a problem getting straight line motion since individual motors vary in their performance. Initially, I set up test devices so I could measure each of my motors and then select well matched pairs. This turns out to be expensive. Sometimes I had to buy 5 motors to get a good pair. More important; my robots operate for hundreds and hundreds of hours while stopping and starting on sub-second intervals. This causes the motors to wear over time and they don't wear evenly, so motor pairs that started with performance curves no longer match in a few months. To overcome this I use software to balance the motors by commanding the slow one to go a little faster. Now, minor tuneups by measuring and revising the profile keep my robots working well for years. For more sophisticated motor circuits there are better solutions, of course.



Most robotic mark makers are plotter-like, so I choose ballpoint pens or markers that produce the same mark regardless of the speed or direction of the robot. Because I use many marking devices — paint brushes, rollers, sponges, sticks, palette knives, rags and more — I need a brush control that allows all of the robot's dynamics to transfer to the marking device. Through many trials and many, many errors I have learned that loose couplings work much better than rigid ones.

A filmmaker who was filming me painting asked, "If it's art by robots, why are you so busy?" First, it's art with robots. The robot does not make it easier to paint, but does make the painting special. The speed of the robot is set to make good brushwork, but it runs continuously. When I paint by hand I can pause between each brush stroke so there really isn't much of a speed requirement. Not so when working with a robot. The robot keeps walking and responding to what it sees while I load brushes with paint and place them in the robot. I usually work with the robot in a number of sessions each about 20-30 minutes. Then I

have to wait. It is usually not good to have the robot walk through wet paint. Sometimes it looks OK for the robot to walk in wet paint, but the paint can "kick up" from the feet and into the gears and motors which leads to earlier death of these parts. So I work in a session that is a layer or a section of the total image and then study the results and plan the next session while the paint dries. With acrylics in Arizona this is about an hour, but sometimes more for thicker paint. Before I begin a painting I mix more than enough paint colors to last for the total picture. I have a large holder of more than 100 brushes (many are alike). I drop used brushes into water during sessions and clean up all brushes between sessions.

I also use a lot of clamps of various sizes for controlling brush depth and orientation. Early sessions may also use paper cutouts to define initial shapes.

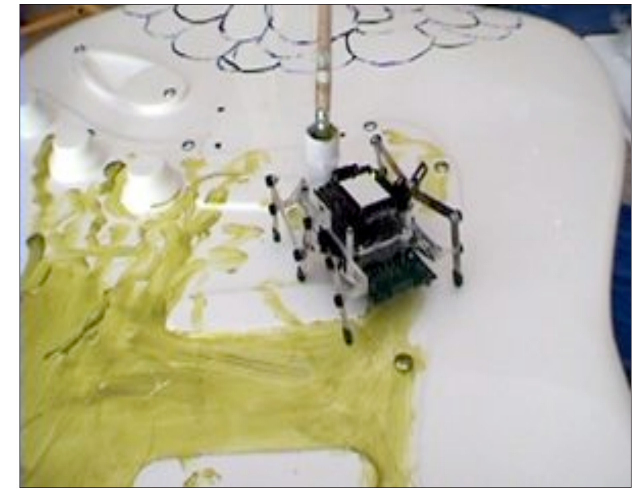
Sometimes I use multiple brushes. This lets colors blend on the canvas and some parallel lines as well One small brush with intense color and a large flat brush with lighter color can produce a blended edge.

The sessions can be very hectic. If I am not ready when a new brush is needed, I might miss a curve or starting point that I felt was important. I prepare borders on the table around the canvas so that the robot will walk back onto the canvas if it walks off. Some sessions go well, almost like a long, long dance. Sometimes the sessions are so frantic, I feel like a mad scientist. What counts in the end, though, is not how the session felt, but what image was made. When I first began, I destroyed or painted out more than 80% of the paintings I made. Now I am better, so I only paint out about 45%.

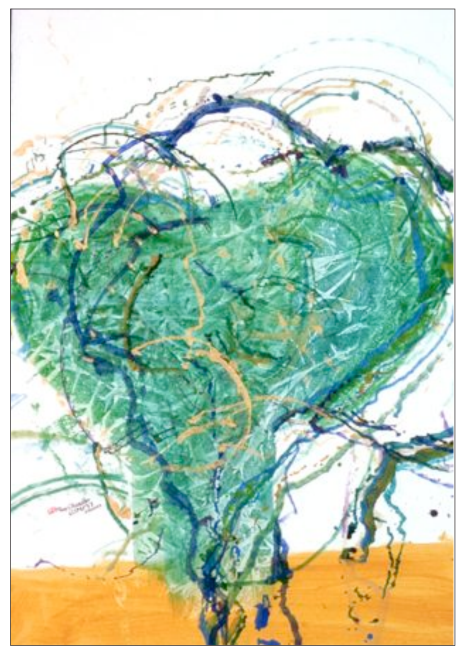
In his book *Jazz*, Matisse said, "In art, truth and reality begin when you no longer understand anything you do or know." In my work, I reach this state of mind in the rhythm and speed of the sessions. There is always in my work a strong conflict between plan and actual and I think much of emotional appeal comes from that conflict.

Recently, I painted a very large guitar as part of Guitarmania, a public art project to benefit Big Brothers Big Sisters. The guitar was an exact replica of a Fender Stratocaster and was ten feet tall. Because none of the surfaces were actually flat, it turned out to be much more difficult than I expected. The robots would fall over or even fall off the guitar completely. I had to work in very short brushstrokes to overcome these problems.

To complete this guitar took more than 230 hours and used up over 200 AA batteries. The guitar was displayed on Mill St in Tempe, AZ very near the ASU campus for about four months and then was auctioned for charity and is now in the lobby of a company in Phoenix.



Here are some examples of my work:



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artists using science and technology

ylem [pronounced eye-lem]
-noun

1. Greek: for the exploding mass from which the universe emerged; the material of the universe prior to creation.

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